Wetland Hydrology: determination of the hydrology of Missouri riparian wetlands

Wetland Program Development Grant

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Introduction

This project examined applicability of using river gage data to determine hydrology at a specific riparian site to be adequate for being defined as wetland hydrology, i.e., inundated for sufficient duration to develop hydric soils and support vegetation typically adapted to life in periodically anaerobic soil conditions. Major activities included monitoring surface water levels in riparian wetlands to be correlated with nearby river surface water levels and exploring possibilities to predict duration and frequency of inundation of riparian wetlands in Missouri based upon river stages of adjacent rivers.

Floodplains of rivers receive surface water from relatively high flows, i.e., over-bank flows, of those rivers. As river flow increases, its water surface reaches a point at which its elevation is greater than that of the surface of the adjacent land (riparian areas). The frequency at which a river's water stages reach and exceed the elevation of the adjacent land will equal the frequency at which that riparian area is inundated by surface water from the river.

Three riparian wetland sites in relative proximity to river flow gages were chosen for monitoring of surface water levels. Riparian wetland surface water levels were compared temporally to river gage surface water levels on the river contributing water to each monitored wetland. Statistical flow frequencies for each of the rivers were applied to the respective riparian wetlands for the purpose of characterizing and predicting wetlands being inundated by surface water from their adjacent rivers.

The 1987 U.S. Army Corps of Engineers (USACE) Wetland Delineation Manual provides quantitative criteria for determining the existence of wetland hydrology. To be considered to have the potential for wetland hydrology, during a normal year the area in question needs to be continuously inundated with water for at least five percent of the growing season. A normal year is assumed, on the average, for one out of every two years. The growing season is an average number of continuous days of soil temperatures warm enough for plant growth. Thus if an area is continuously inundated for five percent of its average growing season it may be subject to wetland hydrology. Water surface level recorders can verify whether or not this hydrologic condition exists at a site. This concept was applied to the three monitored riparian sites. This project demonstrates river gage data can be useful for estimating how often and how long inundation occurs in the river's riparian zones as much as several miles up or downstream from the river gage.

In Missouri, five percent of the growing season equates to approximately 8, 9 or 10 days depending on the geographic location of a site within the state. In terms of statistical frequency of occurrence, this project used the 2-year recurrence interval based upon at least ten years of daily records, i.e., the 8, 9, and 10-day duration and 2-year recurrence frequency (${}_{8\ min}Q_{max\ 2}$, ${}_{9\ min}Q_{max\ 2,}$ and ${}_{10\ min}Q_{max\ 2}$) of river flow and riparian inundation were examined. River gage daily data was used to estimate river water surfaces creating continuous inundation of riparian areas for the prescribed duration and frequency. For three riparian areas in Missouri, determinations were made of the minimum water surface elevation that would allow surface water to flow from the river to the riparian area of interest.

Duration and frequency were calculated for long term river gage data of gaging stations from around the state in addition to the three river gages near the monitored sites included in this project. Based upon postulation of correlation between watershed size and the duration and frequencies described earlier, calculation of maximum minimum duration and frequencies of river flow was correlated with drainage areas of the rivers at their respective gages (referred to in this project as the watershed magnitude analysis). Individual station medians of annual maximum minimums were compared to maximum minimum duration with 2-year frequency of occurrence for individual gage stations. Variations in estimating how often river water levels would be up long enough to imply wetland hydrology at sites adjacent to those rivers is presented in Table 5.

During implementation of this project a publication was released by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) describing procedures similar to those established here. The NRCS publication, Hydrology Tools for Wetland Determination, section 650.1901-Use of stream and lake gages, used medians of annual extreme values which approximate those with a 50 percent probability of being exceeded in any given year. Results from application of the NRCS procedure were compared to results for the duration and frequencies calculated in the procedures established in this project. Results from the two approaches were very similar (Table 5). The following nomenclature was used to represent the annual maximum of a minimum flow with specific multiple day duration and frequency of occurrence.

$${}_{ith\ min}Q_{max\ kth}$$

where i is duration in units of days, Q is an annual maximum value of minimum stream flow in units of cubic feet per second with ith days duration, and k is frequency of occurrence of Q in units of years.

The automated approach used in this project applied a statistical skew to adjust for individual station data tendencies. Adjusting for skew may improve applicability for comparing results from multiple gages and developing regional constants for the relationship of drainage area and ${}_{8\ min}Q_{max\ 2}$, ${}_{9\ min}Q_{max\ 2}$, and ${}_{10\ min}Q_{max\ 2}$ discharges. Computer software was developed to perform the calculations of streamflow duration and frequency of occurrence examined in this project.

Acknowledgments

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For their support in carrying out this project, thanks to Steve Mahfood, director of the MODNR and Mimi Garstang, director of the GSRAD.

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Selection process for monitoring sites

Criteria for selecting sites were:

- Sites must be in riparian areas receiving overbank flooding.
- Sites will be located on a stream or river with a United States Geological Survey (USGS) stream gage having a record length of at least 10 of the most recent years of daily mean flow.
- Sites will be located on unregulated streams.
- To ensure accessibility of data collection sites, potential project sites will be located on public lands.

Geographic Information Systems (GIS) were applied to selecting potential sites for the monitoring portion of this project. GIS data included computerized geographic files of county boundaries, public land boundaries, USGS streamgage locations, hydrography, National Wetland Inventory (NWI), and Digital Raster Graphs (DRG) of USGS 7.5 minute quadrangle topographic maps.

GIS computer software applied in this project were Environmental Systems Research Institute, Inc. ARC/Info and Arcview. GIS analysis was performed upon the geographic files. To determine which gaging stations were in the proximity of public lands, “buffer zones” were created around the boundaries of public lands. These were geographic areas whose boundaries extended a specified uniform distance beyond public land boundaries throughout the state. Buffer zones were created ranging from 1 kilometer to 5 kilometers. Figure 1 illustrates an example of 1 kilometer buffer zones around public lands in the vicinity of the lower portion of the Platte River basin. Gaging stations within the public lands buffer zones were identified. Hydrography was examined at each of those gaging stations to determine whether a portion of the stream being monitored was within the nearby public land boundary. Gaged streams passing through nearby public lands were retained as a list of sites to be examined for existing riparian wetlands to be monitored. The NWI was examined for wetlands existing near the gaged streams on public lands.

State and federal Agency wetland staff were contacted for suggestions of sites to consider for monitoring. Most suggestions included the larger managed wetlands within Missouri. Such sites are typically not in riparian areas of unregulated streams or have controlled hydrology to assure saturation/inundation for prolonged periods. For example Missouri River riparian areas were not included due to extensive flood control from its mainstem reservoirs. Most waterfowl refuges have intensively controlled hydrology.

Soil surveys were also used to consider sites for inclusion in this project. Sites meeting some of the project criteria were reviewed for mapped hydric soils.

Unregulated streams with U.S. Geological Survey (USGS) stream gages were ascertained with a list of such streams provided by the Missouri District USGS Water Resources Division. Other gage data was queried and extracted from USGS records stored in databases maintained by that agency and published data distributed in computer format by Hydroshpere, Inc.

Results of GIS analysis for the selection criteria revealed approximately twenty suitable gages. Field visits were then conducted to those sites. Reconnaissance was also conducted at other longterm gage sites to look for riparian wetlands not appearing in the GIS/public lands/soil survey reviews. On-site evaluations revealed only a couple of sites with riparian wetlands present on public land. A third site was discovered adjacent to public land and along a river within one of Missouri's more well-known wetland complexes. This site was deemed suitable in light of the fact that the landowner was very receptive to a monitoring station being established there and search efforts had been exhausted resulting in a lack of sites from which to choose.

Most potential riparian wetlands we visited did not appear to qualify as jurisdictional wetlands. They included either very sandy soils or soils lacking hydromorphic characteristics or sites lacked hydrophytic vegetation. Similar findings often result in riparian areas as soils there are often too sandy or young enough in the form of recently deposited sediment to lack visible hydromorphic characteristics.

A few other sites that may have been suitable were eliminated from consideration based upon accessibility for gage maintenance or extent of anthropogenic alterations to the landscape. All watercourses with longterm stream gages and potential riparian wetlands had some form of artificial alterations to the landscape. We were fortunate to find the three sites that were chosen for this project.

Monitoring site locations

Locations of the three monitoring sites:

Platte Falls Conservation Area (CA)

The monitored wetland is linear shaped situated in a floodplain between two other linear shaped wetlands. All three could be considered swales, perhaps high flow channels before artificial levees were constructed in the Platte River floodplain. The site is within the southwest portion of Platte Falls CA adjacent to the left bank of Platte River 0.7 miles upstream from the U.S. Interstate Highway 29 bridge in southern Platte County.

Arrow Wood Conservation Area (CA)

The monitored wetland is an oval shaped shallow depression with its length parallel to the present river channel and situated in a floodplain 225 feet north of North Fork Salt River. It is within the southwest portion of Arrow Wood CA adjacent to the left bank of North Fork Salt River 1050 feet downstream from the Missouri Highway 15 bridge in central Shelby County.

Little Osage River oxbow

The monitored wetland is a shallow oxbow pond of the Little Osage River. The site is within private land south of the right bank of Little Osage River 3.8 miles upstream of the U.S. Highway 71 bridge in northern Vernon County.

Figure 2 illustrates locations of the three sites in the state of Missouri. Figures 3, 4, and 5 illustrate locations of the each of the three sites as seen with digital orthoquad aerial photography extending from the monitoring site to the related river gage. For the Little Osage oxbow site, a digital orthoquad (DOQ) including the location of the river gage was not available and was substituted with the topographic map digital raster graph (DRG) of the same quadrangle as is seen in the eastern edge of the illustration. Monitoring sites are designated with a green boundary. River gage locations are designated with a red dot. River name and direction of flow are also designated.

Monitoring site characteristics

<u>Soils</u>

The Platte Falls CA monitoring site consists of soil classified in the Platte County Soil Survey as part of the Colo Series and silt loam phase, described as deep poorly drained soil formed in thick deposits of silty alluvium. Flooding frequency and duration are described in the Survey as frequent and very brief to long. Taxonomic Subgroup is Cumulic Haplaquolls. Colo Series is a hydric soil as listed with the National Technical Committee for Hydric Soils (NTCHS).

The Arrow Wood CA monitoring site consists of soil classified in the Knox, Monroe, Shelby Counties Soil Survey as part of the Arbela Series and silt loam phase. Taxonomic Subgroup is Argiaquic Argialbolls. The Arbela Series is a hydric soil as listed with the NTCHS.

The Little Osage oxbow site is classified in the Vernon County Soil Survey as water. Soil surrounding the oxbow pond is classified as part of the Radley Series and silty clay loam phase, occurring on 0 to 2 percent slopes formed in stratified silty alluvium washed from nearby upland areas. The Radley Series is not a hydric soil according to the NTCHS listing.

<u>Vegetation</u>

All three sites were in forested floodplains with typical bottomland vegetation. Overstory species at all three sites were of mature ages as evidenced by the large average diameter and height. Figures 17, 18, and 19 also indicate mature forests with the appearance of large tree sizes in the 3 aerial photographs taken in 1958 and 1962. Similarity between the three older photographs with those of Figures 2, 3, and 4 taken during the mid 1990’s and site visits during this project indicates the forest (as well as the landscape) surrounding each site has remained relatively undisturbed during the last 50 years.

Within the delineated wetland of each site there was little understory vegetation. Only the Arrow Wood CA site had significant vegetative composition actually in the wetland. The predominant species there was Acer saccharinum (Silver Maple). During the 1999 growing season there was an abundance of saccharinum seedlings appearing to have sprouted during the spring of that year. During the summer of 2000 at the fringe of the wetland boundary hydrophytic species appeared including Urtica Dioica (Stinging Nettles), Carex grayi (Grays sedge), and Polygonum pensylvanicum (Pinkweed). Among the three monitoring sites, Arrow Wood CA was inundated the least.

At the Little Osage oxbow there was almost no vegetation within the delineated wetland/oxbow. It remained inundated for most of the two-year monitoring period. Along the perimeter of the wetland was an abundance of tree species including Quercus macrocarpa (Bur Oak), Quercus palustris (Pin Oak), Carya cordiformis (Bitternut Hickory), and Carya laciniosa (Shellbark Hickory).

At the Platte Falls CA site there was also almost no vegetation within the delineated wetland where surface water was present during much of the two-year monitoring period. Just beyond the wetland and several feet higher in elevation were Populus deltoides (Eastern Cottonwood), Platanus occidentalis (American Sycamore), Acer saccharinum, and Urtica dioica. As was found at the Arrow Wood CA site, newly sprouted saccharinum seedlings were present in the spring of 1999. It appeared to be a good year for seed dispersal and germination with the wet autumn of 1998 establishing abundant moisture in bare soils due to prolonged inundation.

National Wetland Inventory

The U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) classified the Platte Falls CA monitoring site as “Palustrine, Forested Broad Leaf Deciduous, Temporarily Flooded” wetland. Although the Arrow Wood CA monitoring site is classified by the NWI as a non-wetland, it did meet the criteria of being a wetland as defined by the USACE 1987 Wetland Delineation Manual. The monitoring site could be appropriately classified the same as other sites in the vicinity of the monitoring site along that reach of the North Fork Salt River which were identified by the NWI as “Palustrine, Forested Broad Leaf Deciduous, Temporarily Flooded” wetland. The Little Osage oxbow has an NWI classification of “Palustrine, Unconsolidated Bottom, Semi-permanently Flooded” wetland.

Physiography

Platte River and North Fork Salt River are located within the Glaciated Plains Division (Thom and Wilson, 1979) of the Central Lowlands physiographic Region, described by Fenneman (1938) as Dissected Till Plains. Nearly level landscapes of the Glaciated Till Plains were formed from glaciation over 1 million years ago during advancement of the Nebraskan drift sheet and further leveled during glaciation from the Kansan drift sheet retreating approximately 500,000 years ago.

Platte River is further classified as within the Western Section of the Glaciated Plains Division characterized by loess-dominated topography and soils as well as the driest climate in the state. Much of pre-settlement stream drainages consisted of prairies as did the uplands with some presence of deciduous forest. North Fork Salt River is located in the Eastern Section of the Glaciated Plains Division characterized by flat claypan soils and rugged river breaks. Till soils occupy the uplands and alluvial soils predominate in the bottomlands.

Little Osage River is within the Osage Plains Division corresponding with Fenneman's Osage Section of the Central Lowlands Region. The Natural Divisions of Missouri (Thom and Wilson, 1979) did not subclassify the Osage Plains Division citing a lack of differentiation within the Division to warrant subtypes. The Division is characterized as

70 percent prairie before settlement with occurrences of forest “especially in the river bottoms”.

Land use in the three river basins

The three river basins experience similar land uses as do many basins outside of metropolitan areas and within similar physiographies. Catalogued land uses of the U.S. Geological Survey Nationwide Land use Classification are presented in Table 6. Agricultural crop and pasture land use covers most of each of the basins. Urban land covers approximately 1% of each of the basins. Forest land covers a minor portion of each basin. Land use in the three basins is typical of rural areas in northern and west central Missouri.

It had been anticipated that land uses of the river basins for the stream gages used in the watershed magnitude analysis may be included in regression of ${}_{ith\ min}Q_{max\ kth}$ (from page 2), duration and frequency, with river basin parameters affecting stream flow. Due to the high correlation of drainage area versus ${}_{ith\ min}Q_{max\ kth}$, inclusion of land use was not pursued.

Surface water sources of the monitoring sites

All three sites received surface water at least once during the monitoring period from overflow of their respective adjacent rivers. All three sites also received water from other sources which could have included surface as well as subsurface water. Subsurface water levels were not monitored. The magnitude of increased water levels in the absence of overbank contributions was small compared to increases due to river overbank contributions. Most increases in wetland water levels were created by contributions from river overbank flows into each of the three monitored sites.

The Platte Falls CA monitoring site held water during much of the two-year monitoring period. The water was often relatively low in the landscape depression the wetland exists within. The Little Osage oxbow site had a substantial pool of water throughout much of the two-year monitoring period. The landowner indicated ‘the oxbow never goes dry’. Arrow Wood CA site had no surface water present during much of the two-year monitoring period. The site did have surface water for at least eleven consecutive days during both growing seasons of the two-year monitoring period.

Precipitation

Nearby daily precipitation was compared to water levels at the monitoring sites to identify the effect of local precipitation upon wetland water levels. Daily precipitation is included in the hydrographs of wetland surface water levels and respective river water levels in Figures 6, 7, and 8. At each of the three monitoring sites during the two-year monitoring period there were a few occasions of a slight rise in wetland water levels without surface flow from their adjacent rivers.

For the Platte Falls CA site, the nearest precipitation gage with daily totals was located six miles south at the Kansas City International Airport in Platte City. Wetland water surface elevations as well as river water surface elevations reflected major daily precipitation occurrences recorded at Platte City. While wetland water elevations were affected by river water elevations that exceeded ground surface elevations at the wetland, on several occasion wetland water elevations did increase with the occurrence of local precipitation. The drainage area of runoff into the wetland is approximately 4 acres of bottomland hardwood forest. Examples at Platte Falls CA included late September 1999 and late May 2000 when rainfall totaled 3.21 inches during a three-day period and 3.31 inches during a seven-day period respectively.

For the Arrow Wood CA site, the nearest precipitation gage with daily totals was located 18 miles north at the City of Steffenville. Water surface elevations in this wetland also reflected major daily precipitation occurrences recorded several miles away. Drainage area of runoff into the wetland is approximately 3 acres of bottomland hardwood forest. Examples of notable local precipitation events lacking overbank flows at the Arrow Wood CA site included mid March 1999 and late June 1999 when rainfall totaled 1.86 inches during a four-day period and 2.17 inches during an eight-day period respectively.

For the Little Osage site, the nearest precipitation gage with daily totals was located eight miles south at the City of Nevada. At the Little Osage site as with the other two sites, major occurrences of local precipitation contributed to minor increases of inundation depths. Eight acres drain into the monitoring site. An example of influential local precipitation was late June 2000 when rainfall totaled 6.88 inches during a twelve-day period.

Palmer Drought Severity Index

An aspect of wetland hydrology determination based upon site conditions at a point in time is estimating how often to expect the wetland to be as wet as it is at the time of an observation, on-site or remotely. In terms of meteorology and soil moisture, one approach is using the Palmer Drought Severity Index (PDSI) which can be useful for depicting the hydrologic extremity of conditions applied over a climatic region. The National Oceanic and Atmospheric Administration divides Missouri into six divisions each of which is designated with a calculated PDSI. A look at monthly PDSI values over the two-year monitoring period and the year preceding the monitoring period provides a description of how relatively wet or dry was the meteorology of the site and (for riparian areas) the drainage basin of the adjacent river. Table 1 presents monthly PDSI values during the two-year monitoring period (1999 - 2000) as well as the preceding year (1998). The table also presents monthly precipitation totals, long term monthly averages, and monthly percent of average for 1998, 1999, and 2000.

PDSI divisions 1,2 and 3 in Missouri are applicable to the three monitoring sites. In all three divisions, the monthly PDSI values for late 1998 through early 1999 were in the range of “unusually moist” to “extremely moist”. In mid 1999 conditions became dryer with below average monthly precipitation totals that continued into 2000 producing PDSI values in the range of “moderate drought” to “severe drought” conditions. For the Platte Falls CA (division 1) and Arrow Wood CA (division 2) sites the PDSI values there increased to “normal” and “moist” for the second half of 2000. At the Little Osage site (division 3), below average precipitation dominated to the end of 2000 with resultant

PDSI values expressing “moderate drought” conditions. Water levels or lack thereof at each monitoring site are reflected in the trend of monthly PDSI values.

Examination of historic data sets of PDSI values can contribute to understanding how often to expect the specified dry or wet conditions to occur. Drew and Chen (1997) present accumulated frequencies of PDSI values for the historic data set of the monthly PDSI (1895-1994) for each division in Missouri. The wet conditions of late 1998 that existed in each of divisions 1, 2 and 3 have been at least as wet during approximately 4 percent, 25 percent and 12 percent of the 100-year period, respectively. The driest conditions of mid 1999 into 2000 in each of divisions 1, 2 and 3 have been at least as dry during approximately 10 percent, 6 percent, and 10 percent of the 100-year period, respectively.

Inundation

At all three sites, overbank flows from the adjacent river were the major source of surface water to the wetland during the two-year monitoring period. River water levels coincided closely with the wetland water levels while the river was above initial inundation elevations of the wetland (Figures 9, 10, and 11). Most surface water inundating each of the wetlands was received during these riverine flood events.

Following inundation from overbank flow of the adjacent river and lowering of the river water level below flood stages, initial loss of water was as surface drainage from the wetland into the river channel by way of drainage channels from each wetland. Retention of surface water in the wetland was initially controlled by minimum elevations in the drainage channels. These minimum elevations were higher than much of the wetland creating a dam effect in each drainage channel and pooling water in the wetland. At all three sites, the minimum elevation of a drainage channel was the elevation the adjacent river water level exceeded as initial inundation of the wetland from the river began. This was the river stage elevation used to calculate how often a wetland received water from the adjacent river, i.e., calculation of exceedence probabilities for river flows inundating the wetland.

Regarding the use of river flow gage data to determine the presence of wetland hydrology, frequency of inundation may be more pertinent than duration of inundation. At all three sites, river water levels did not remain at stages higher than the initial wetland inundation elevation long enough to assume wetland hydrology. Once inundated, all three wetlands did maintain a pool of surface water at least several days after river stages fell below the stage necessary to inundate the wetland. Statistical analysis of river gage data indicates river water levels keeping the wetland continuously inundated for periods long enough to assume wetland hydrology will occur only once every several years with frequency of occurrences approximating: Platte River at Sharps Station, 5 years; North Fork Salt River near Shelbina, 35 years; Little Osage River at Horton, 5 years (Table 2).

Flood stage

In this report, flood stage is the numeric river stage for a specific gage, designated by the National Weather Service (NWS) as the stage at which minor flooding occurs with

"…minimal or no property damage. However, some public inconvenience is possible." Many river gage stations have a NWS designated flood stage. Riparian areas usually begin to receive water from their adjacent rivers when stream flow reaches flood stage.

At all three monitoring sites, the wetlands began receiving river water when the river stage was approximately at the NWS designated flood stage. At the river gage on the North Fork Salt River near Shelbina there is no NWS designated flood stage. The river stage at which the wetlands began receiving river water was essentially the river's flood stage based upon observations in the proximity of the river gage.

In Table 2, river flood stage is compared with the ${}_{8,\,9\text{ and }10\text{ min}}Q_{\text{max }2}$ and their resulting river stages. For most river gages included in this project, the ${}_{8,\,9\text{ and }10\text{ min}}Q_{\text{max }2}$ produced river stages well below flood stage.

Maximum minimum durations and frequencies

Streamflow data was analyzed to determine how often river flow remained greater than a predetermined minimum amount for a specified consecutive number of days. Duration and frequency analysis was conducted on the same streamflow data calculating statistical probabilities indicating how often rivers would be expected to remain at greater than a predetermined minimum flow for a continuous length of time beyond a minimum duration. In this application of statistical analysis, the pertinent duration and frequency is termed an eight, nine or ten-day duration with a one-in-two year frequency of occurrence. In other words, the occurrence of streamflow for a period of at least eight consecutive days with the expectation of recurring, on the average, every other year.

Procedures

A streamflow data set consisting of several years of daily average flows was extracted from long term stream gage records. Each year of daily values was examined identifying consistent multiple-day durations of daily values. Two of the three monitoring sites were located in counties that have ten days as five percent of their average growing season lengths. The 10-day duration will be used in describing the procedures presented here, i.e., a moving 10-day data set was created for each day of the year. This generated 355 data sets, each having 10 daily flow values, for each year of daily flow records. Each of these yearly data sets of moving 10-day periods was examined for the minimum daily flow that occurred during each 10-day period. This generated yearly data sets of 355 10-day minimum flows.

The new data set of minimum values was compiled for the most recent ten and twenty years as well as all years of the long term (multiple year) streamflow data set. Only the river gage on the North Fork Salt River had more than twenty years of daily mean stream flow records. From each annual set of minimum values, the maximum value in that data set was saved to another set of values. That created a data set of annual maximums from their respective moving durations of 10-day minimum values. Medians were calculated for the individual station annual maximum minimums. Calculation for frequencies of occurrence was applied to the individual station annual maximum minimums.

Results and discussion

At the three gages monitored in this project the appropriate ${}_{ith\ min}Q_{max\ 2}$ was much less than bankfull discharge with a corresponding river stage several feet below the stage of bankfull discharge. Results of the calculations are presented in Table 2 including medians of annual maximums for the minimum flow during 9 or 10-day duration, ${}_{9\ or\ 10\ min}Q_{max\ 2}$, the frequency of occurrence for 9 or 10 day duration of bankfull discharge and application of the regression equations developed in the watershed magnitude analysis described later in this report. Comparison of ${}_{ith\ min}Q_{max\ 2}$ for record lengths of the most recent 10, 20 and all years of recorded daily stream flow, reflected multiple years of relative wet or dry meteorology that occurred during those time periods. The most recent 10 years produced higher ${}_{ith\ min}Q_{max\ 2}$ values. This was also observed for gage data examined in the watershed magnitude analysis.

Future studies might attempt to improve correlation by grouping gage data by region – physiography, climate, hydrologic unit, etc. More accurate results for an estimate of ${}_{ith\ min}Q_{max\ 2}$ at a specific ungaged site might be obtained by performing regression with streamflow data from several long term gages surrounding the site within the same region.

Applicability

The statistical information resulting from this analysis would be useful for wetland identification, delineation, and restoration. In terms of wetland identification and delineation for landscapes (riparian areas) that receive much of their water from a riverine surface water source, this information could assist in determining whether a site is inundated frequently enough and for an adequate length of time to induce the formation of hydric soils and the establishment of hydrophytic vegetation. At riparian sites that have elevation data for the terrain, a point in the landscape under proper conditions might be determined for which higher elevations will not be inundated frequently enough, nor for adequate duration, to assume the formation of hydric soils and the establishment of hydrophytic vegetation.

At all three sites, initial inundation occurs with river water levels at approximately the top of the river bank, i.e., bankfull discharge. Entry of water is through a drainageway connecting the river with the adjacent wetland. The minimum river water elevation that contributes water to the wetland via the drainageway is the elevation that corresponds to the discharge used to calculate frequency of inundation of the wetland.

Design of water diversion canals intended to deliver water often enough to define an area as a jurisdictional wetland might have channel bottom elevations that approximate the elevation of river stage resulting from a streamflow equal to the ${}_{8,\ 9\ or\ 10\ min}Q_{max\ 2}$. Wetland bottom elevations would need to be less than or equal to the elevation of the water diversion canal to allow surface water to flow into the wetland when river flow approximates the ${}_{8,\ 9\ or\ 10\ min}Q_{max\ 2}$.

All three sites had a common characteristic of ponding of water after the river level dropped below the elevation of the wetland. At all three sites a feature on the ground existed that created a higher elevation of the ground surface between the wetland and the river channel causing pooling of water. Where peak flows in a stream inundate riparian areas at least once during the growing season of a normal year only minimal placement of soil may be required to pool water and maintain inundation for at least eight to ten days.

Peak flow from the river

As was seen in the three monitored sites, many riparian wetlands may have adequate inundation due to a depressional landscape that captures a pool of water remaining after water level in the adjacent river recedes to below the elevation of the wetland. Under such a scenario peak flows are an important factor for providing surface water to riparian wetlands. Assuming the wetlands monitored in this project are typical of riparian wetlands in Missouri, duration of inundation need only be long enough to fill the riparian wetland. The question then becomes what duration of inundation is enough to fill the riparian landscape depression?

The three monitored sites required probably less than an hour of overbank flow from the adjacent wetland before their water levels were equalized with the water levels of the adjacent river. Surface water from the adjacent rivers entered the wetlands in two ways; through a channel (ditch, drainageway, etc.) connecting the river channel with the wetland and by way of overland flow along a general length of the river bank, i.e., river water flowing over the top of much of the bank along a river reach and moving across the floodplain to the wetland.

At the three monitored sites, only when water levels in the rivers rise to no more than approximately bankfull would the wetlands be filled only through a connection channel. Many times when a river reaches flood stage it may continue to rise well above flood stage and generate widespread overbank flow. Under such conditions a wetland of similar dimensions as those in this project would fill within a few minutes. However the connection channel could fill such sites before the river actually starts widespread overbank flow.

To illustrate the significance of peak flow, the two-year frequency of occurrence for peak daily mean flow was calculated (Table 5) using the daily flows for each of the river gages included in this project. At many of the gages analysed, daily peak flow was an order of magnitude larger than the eight-day two-year maximum-minimum duration and frequency flow. In terms of river stage, the two-year peak flow is usually well above flood stage. Near the Arrow Wood CA on the North Fork Salt River the two-year peak flow is approximately six feet above bankfull discharge and eleven feet above the stage of the 8-day 2-year maximum-minimum duration and frequency flow. At the Platte Falls CA on the Platte River the two-year peak flow is also approximately six feet above bankfull discharge.

Correlation of wetland stage with river stage

<u>River channel gradients</u>

Channel gradients for stream reaches between the monitored sites and their corresponding river gages were estimated using surveyed water surface elevations adjacent to the monitored sites and water surface elevations at the river gages when streamflow was very low and water depth in the rivers was negligible. Channel lengths were determined from USGS GIS digital line graph hydrography computer files.

The Little Osage River reach from the Little Osage River oxbow to the stream gage downstream at Horton is approximately 3.8 miles in length. The decrease in channel elevation from the river at the oxbow to the stream gage at Horton is 4.5 feet creating a channel gradient of 1.2 feet per mile.

The Platte River reach from the Platte Falls CA monitoring site to the stream gage upstream at Sharps Station is approximately 7.3 miles in length. The increase in channel elevation from the river adjacent to the wetland and the stream gage at Sharps Station is 12.7 feet creating a channel gradient of 1.7 feet per mile.

The North Fork Salt River reach at the Arrow-Wood CA monitoring site to the stream gage upstream at Missouri Route 15 is 1050 feet in length. The increase in channel elevation from the river adjacent to the wetland to the river gage at the Route 15 bridge is 6.3 feet. A low water dam exists 450 feet downstream of the bridge for the purpose of pooling water for a water supply intake. During low flow conditions the low water dam creates a decrease in water surface elevation of several feet and accounts for most of the channel gradient between the river gage and the wetland. The channel gradient for the stream reach length of 1050 feet is 31.7 feet per mile. This gradient is much higher than would be expected for other reaches of the lower North Fork Salt River. Using the USGS 7.5 minute topographic map to estimate changes in elevation in the five mile river reach upstream of the Route 15 bridge the channel gradient is estimated as 1.8 feet per mile.

River water surface gradients at high flow

Elevations of peak stages for each flood event occurring during 1999 and 2000 were compared for each river gage and its respective wetland gage. Each site experienced at least four river flood events for which peak stages were recorded in the monitored wetlands. At all three sites, variation in occurrence of peak stage elevations between the river gage and wetland gage were within 1.5 feet. Peak stage gradients between river gage stage and wetland stage at the Platte River and Little Osage sites closely resembled the respective channel gradients. This gives an indication that channel gradient may be a reliable estimate of peak stage gradient when attempting to correlate a riparian wetland site with a nearby river gage for discharges near bankfull. This would be applicable in stream reaches free of structures that significantly alter the channel gradient or hydraulics. Even in stream reaches with such structures, flows near bankfull discharge may diminish the effects of structures altering channel gradient.

At the North Fork Salt River site, correlation of peak stage elevations between the river gage and the wetland gage illustrated affects a low water dam can have on water surface gradients during high flow. Difference in peak stage elevation between the river gage stage and wetland stage, which averaged 0.39 feet, was not similar to the change in channel elevation of 6.3 feet primarily created by a low water dam. This demonstrates how a low water structure in a channel has a diminished effect on hydraulics during high flows in the river.

A major objective of this project was to correlate river water levels with riparian wetland water levels. Correlation calculation was conducted for each river flood event inundating each riparian wetland monitoring site. As shown in table 3, Gage Correlations, for all three rivers the coefficient of correlation (R) was high. For the Platte River, the correlation of river peak elevation with wetland peak elevation produced an R value of 0.997 among the four flood events. For the North Fork Salt River, the river peak elevation versus wetland peak elevation correlation produced an R value of 0.999 among the six flood events. For the Little Osage River, the river peak elevation versus wetland peak elevation correlation produced an R value of 0.94 among the five flood events.

Hydraulic connection of river to wetland

At all three sites a small fluvial channel existed in the riparian zone connecting the river with the wetland. Apparently water in these channels would flow in opposite directions depending upon the water levels of the river and the wetland relative to each other.

Land surface elevations between the river and the wetland indicated initial inundation from rising river levels at each site occurred when the river water surface elevation reached the minimum ground elevation within the connection channel (if the wetland water surface elevation was lower at the time). Typically when the river water level decreases to below the minimum ground elevation in the connection channel, water in the wetland will begin to return to the river until the water level in the wetland decreases to below the minimum ground elevation in the connection channel. This is explained with the concept of hydraulic gradient. When the hydraulic gradient slopes from the river to the wetland, water in the connection channel flows toward the wetland and inundation begins. When the hydraulic gradient slopes from the wetland to the river, water flows to the river and the wetland drains water through the connection channel until the water level decreases to below the minimum ground elevation in that connection channel.

Watershed magnitude analysis

Procedures

During this project an effort was developed to correlate watershed size with resultant maximum minimum multi-day streamflows at stream gages across the state. The theorem being as magnitude of watershed drainage area increases, the multi-day high streamflows will increase commensurately. This can be surmised from the fact that significant precipitation events of multiple day duration often create saturated soil moisture conditions. Liquid phase precipitation upon saturated soil becomes run off and streamflow. With saturated soil, volume of streamflow will be largely controlled by precipitation volume received within the watershed.

Streamflow data for selected stream gages from around the state was analyzed for the same multi-day annual maximum minimum streamflow parameters as the three stream gages and respective riparian sites initially monitored for this project. Watershed drainage area for the respective stream gages was correlated with corresponding medians of annual maximum minimum streamflow calculations for durations of eight, nine, and ten days. Frequencies of occurrence calculated with the annual maximum minimums were presented as probability of being exceeded in any given year and fit to a Log-Pearson Type III distribution for probabilities from 0.9999 to 0.0001. Calculations were made with the statistical computer software, Duration Frequency for Windows (WF). The statistical software automatically calculated and adjusted for statistical skew in the annual maximum minimum multi-day streamflows applied to the frequency of occurrence calculations to account for individual station data tendencies. This function was allowed to remain for comparison to the results of calculation of medians of annual maximum minimum multi-day streamflows without adjustment for skew.

Prior to adding the functionality to the software it was necessary to conduct statistical analysis using computerized spreadsheets. This served as an example of applying the procedures recommended and outlined in the 1997 NRCS publication, USDA National Engineering Field Handbook, Chapter 19, Hydrology Tools For Wetland Determination. The method described in Section 650.1901 was applied to streamflow data for the 21 gages included in this effort. Spreadsheet manipulation was performed resulting in the statistical parameters described in Section 650.1901.

For the purpose of improving efficiency of the analysis, software was developed to calculate annual maximum minimum multiple-day duration and frequencies. I worked with Hydrosphere Inc. to add the capability to their statistical duration and frequency analytic software. Hydrosphere Inc. refers to their software as Duration Frequency for Windows (Figure 12). The modified version created for this project is version 2.1. The Water Resources Program is a client of Hydrosphere, Inc. and uses the hydrologic databases distributed by that company. The new software allowed faster calculation of the statistical parameter described above. It has improved our ability to perform automated calculations of these statistical parameters with minimal chance for human error.

Years of daily mean streamflow for each of the 21 stream gages were 1990 through 1999 and 1980 through 1999. Entire period of record data sets of daily mean streamflow for each of the 21 gages generated lower correlation coefficients than did the 10 and 20-year data sets. Due to the lower correlation of entire periods of record, only the 10 and 20-year records were included in the final analyses. The lower correlation coefficients were probably at least partially due to the fact that each gage included a slightly different time period of data. The variation in climatology from decade to decade and even variation in long duration storms from year to year may require correlating data sets with the same years.

Streamflow gage data sets were selected based upon the following criteria.

- Gage is on an unregulated river.
- Daily mean discharge records include at least the past 20 consecutive years and have an applicable stage/discharge rating table.
- Drainage area to the gage is at least 500 square miles.
- Streamflow gage has a designated flood stage as determined by National Weather Service River Forecast Centers.

Results

Duration and frequency calculations as well as medians of annual maximum minimum values for each stream gage were correlated with drainage area of each of those stream gages. In all cases a strong correlation existed between drainage area and the durations and frequencies used in this project. All correlations had a correlation coefficient greater than 0.94. Linear regresssion was applied to the calculated values of ${}_{ith\ min}Q_{max\ kth}$ for each of the gage data sets with drainage area representing the independent variable from each stream gage and ${}_{ith\ min}Q_{max\ kth}$ representing the dependent variable from each stream gage. Table 4 presents the resulting correlation coefficients along with the regressed x and y line slope and y intercept for each regression. Figures 13, 14, and 15 are x and y axis graphical representations of the correlations and best-fit lines of the linear regressions.

Differences between medians of annual maximum minimum values and duration and frequencies adjusted for skew were small especially compared to the differences between ten-year records and twenty-year records. For example, in Figure 13, 8-day two-year maximum minimums estimated with medians and with skew adjusted duration and frequencies were essentially the same whereas the differences between the ten-year records and twenty-year records subjected to the same calculations were much greater. Similar results were seen with 9-day and 10-day durations. This may indicate the significance of individual storm events upon the frequency calculations examined in this project.

For a perspective of river gage stages, river channels and water depths relating to discharges reported here, Table 5 includes river stages equivalent to the calculated ${}_{8\ min}Q_{max\ 2}$, flood stage for each of the stream gages and stage at zero stream flow.

Implications for Restoration

The watershed magnitude analysis indicates most rivers in Missouri do not maintain river stages high enough to inundate their riparian areas for long enough duration to assume wetland hydrology. Instantaneous peak flows may be a more important riverine hydrology parameter for designing a riparian wetland. Where a depression exists in a floodplain and receives inundation periodically, the water may not be present for a duration adequate to induce hydric soils. In such situations a very low dam or berm structure may pool enough water to extend the duration of inundation long enough to induce hydric soil conditions. This could be especially affective where hydric soils are generally thought to exist though wetland hydrology is lacking and redoximorphic conditions are not evident. Higher elevations in a floodplain would be inundated by the river less often. Restoration there may require hydrologic input in addition to flooding from the river. Where the opportunity exists, drainage area of runoff (other than from the river) into the restored site might be increased to provide additional water enough to have wetland hydrology in combination with periodic contributions from the river.

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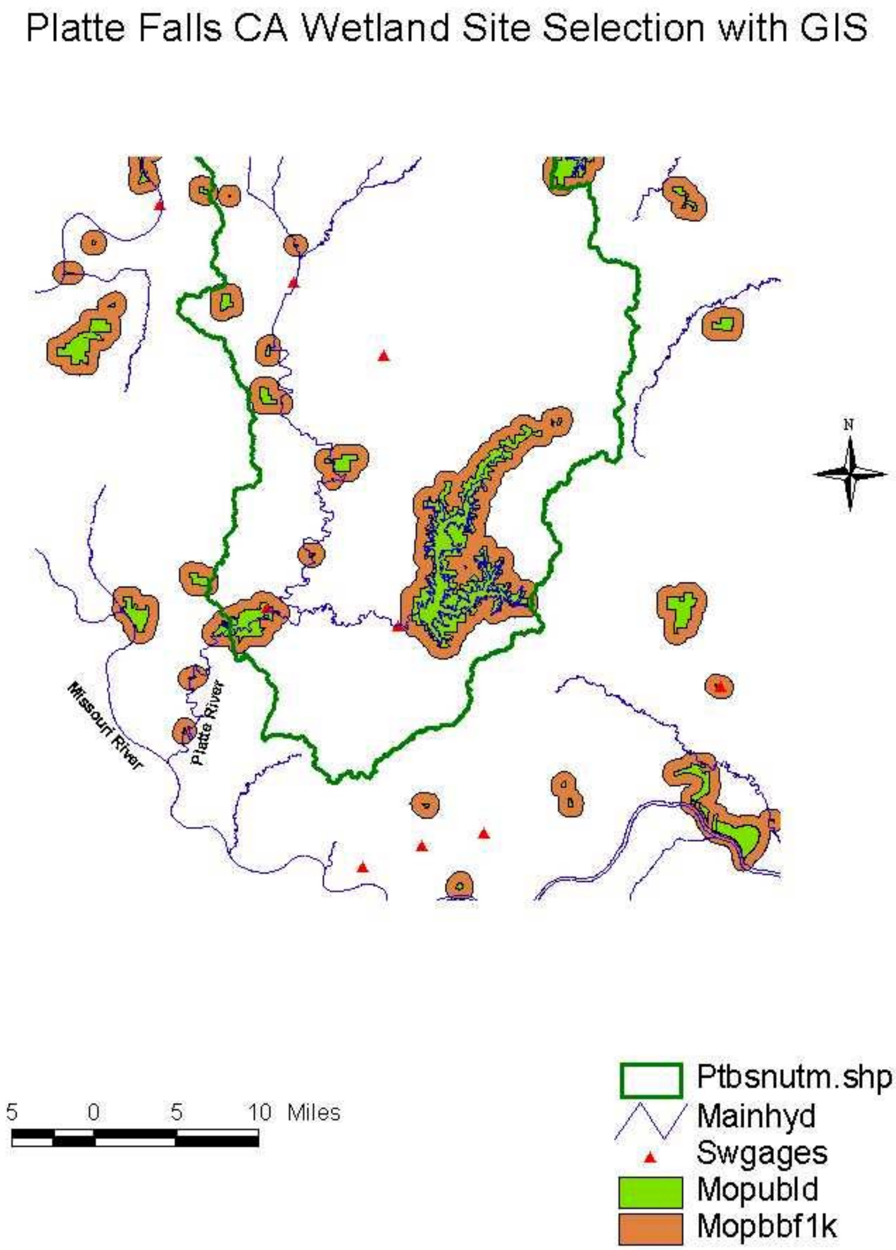

Figure 1. Example of 1 KM buffer zones, including Platte Falls CA.

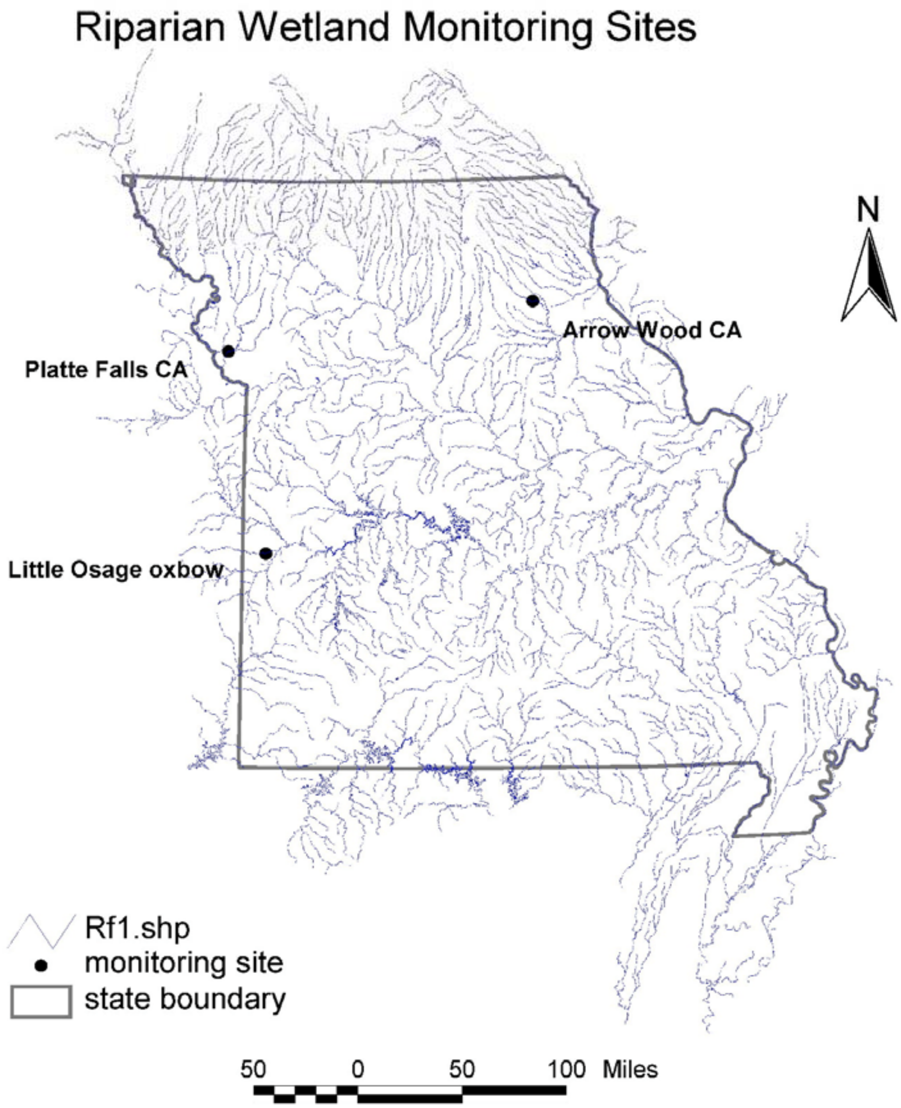

Figure 2. Three riparian wetland monitoring sites in Missouri

Figure 3. Platte Falls CA monitoring site and river gage shown on a DOQ.

Figure 4. Arrow-Wood CA monitoring site shown on a DOQ.

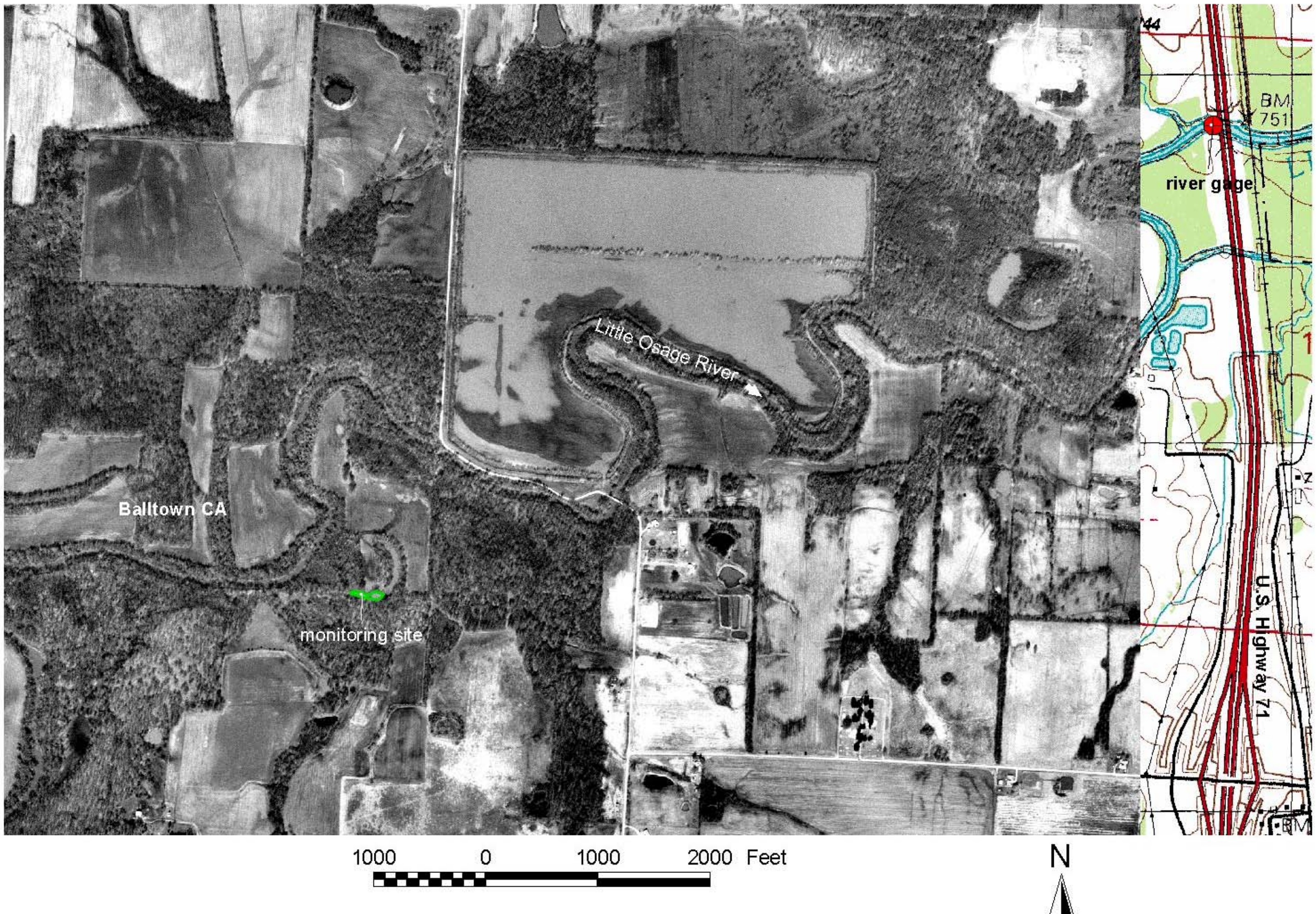

Figure 5. Little Osage River oxbow monitoring site and river gage shown on a DOQ and DRG.

A10

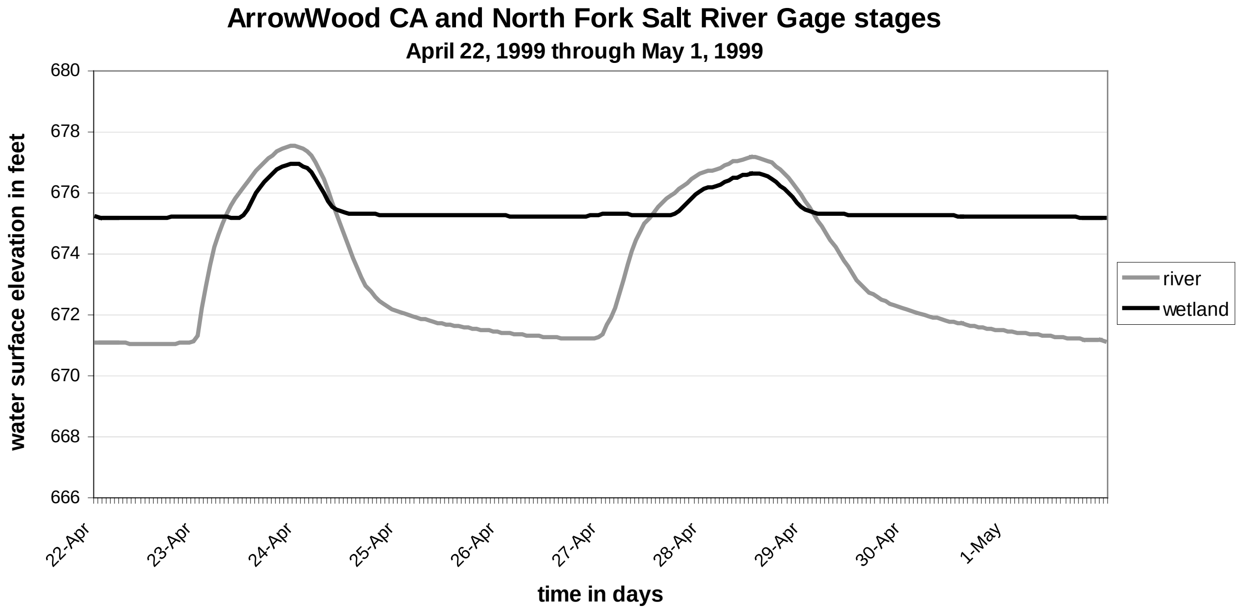

Figure 10. Hourly water surface elevations of Arrow-Wood CA wetland and North Fork Salt River.

A11

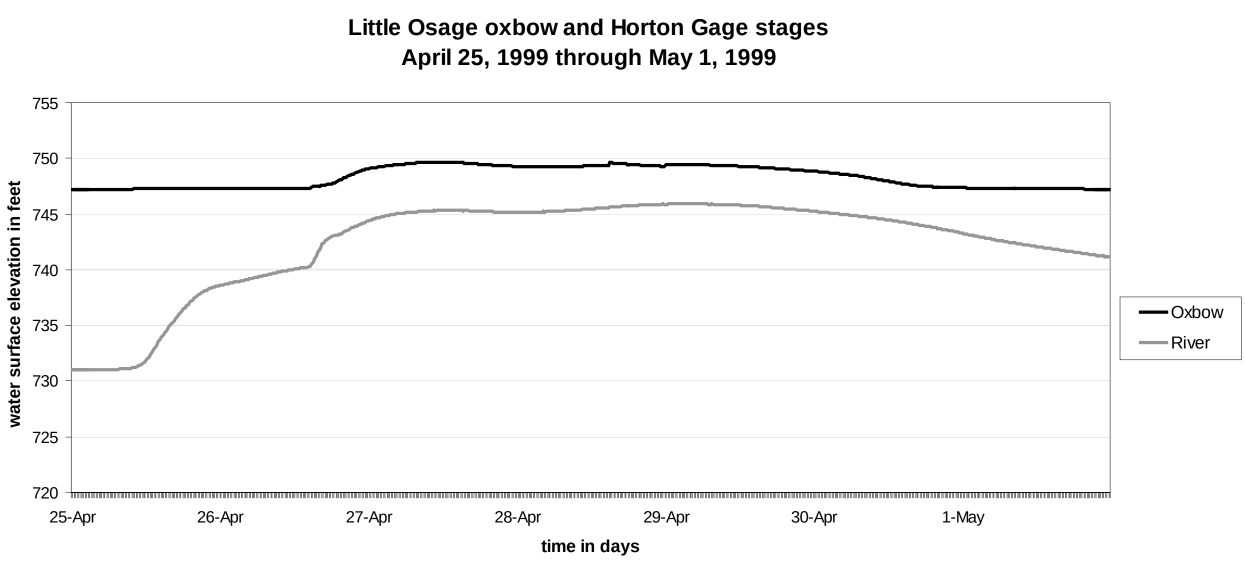

Figure 11. Hourly water surface elevations of Little Osage River oxbow and Little Osage River at Horton.

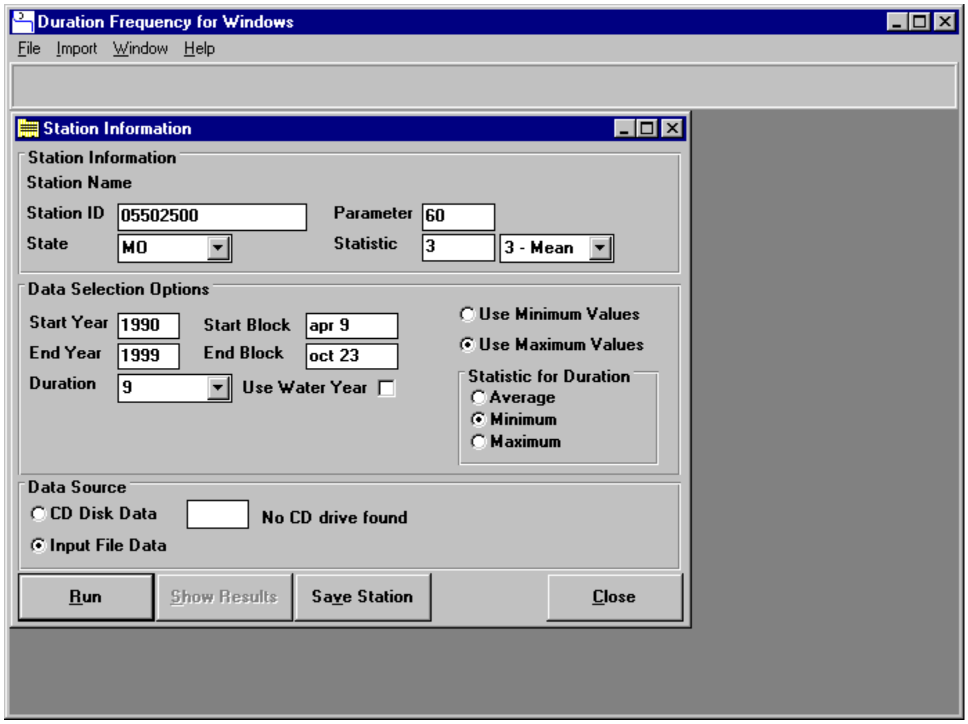

Figure 12. Computer screen image of Duration Frequency for Windows

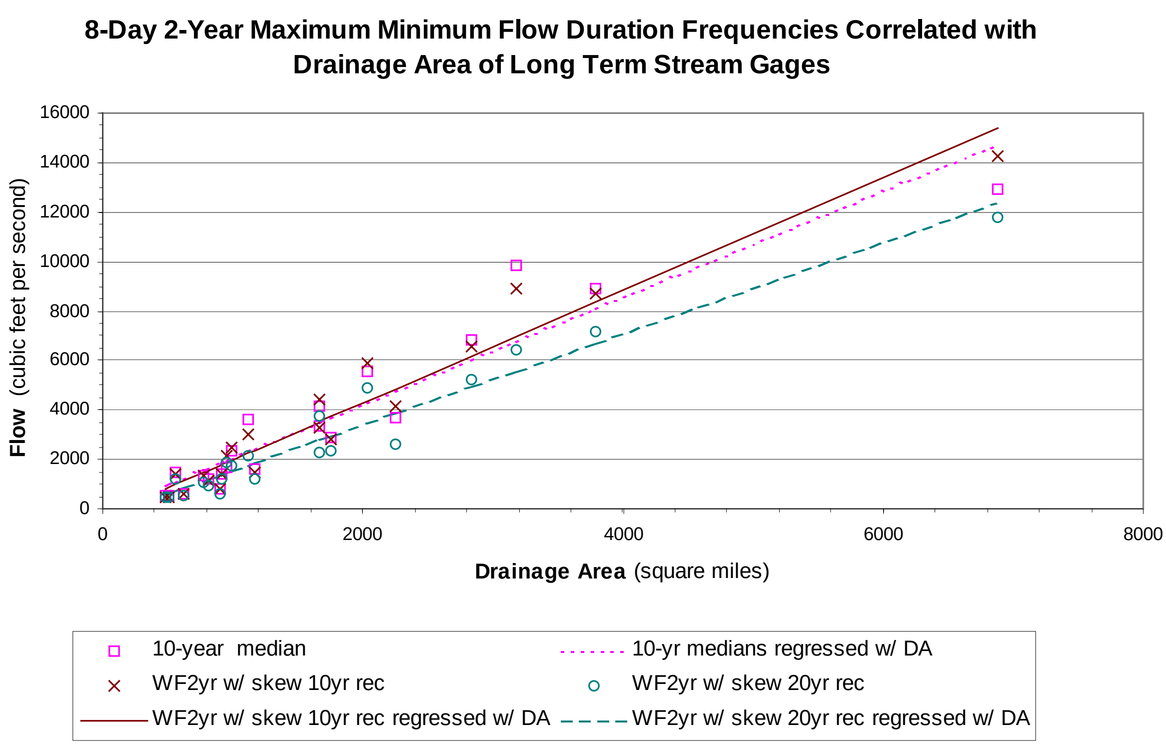

Figure 13. Graph of linear regressions of ${}_{8\ min}Q_{max\ 2}$ with drainage area.

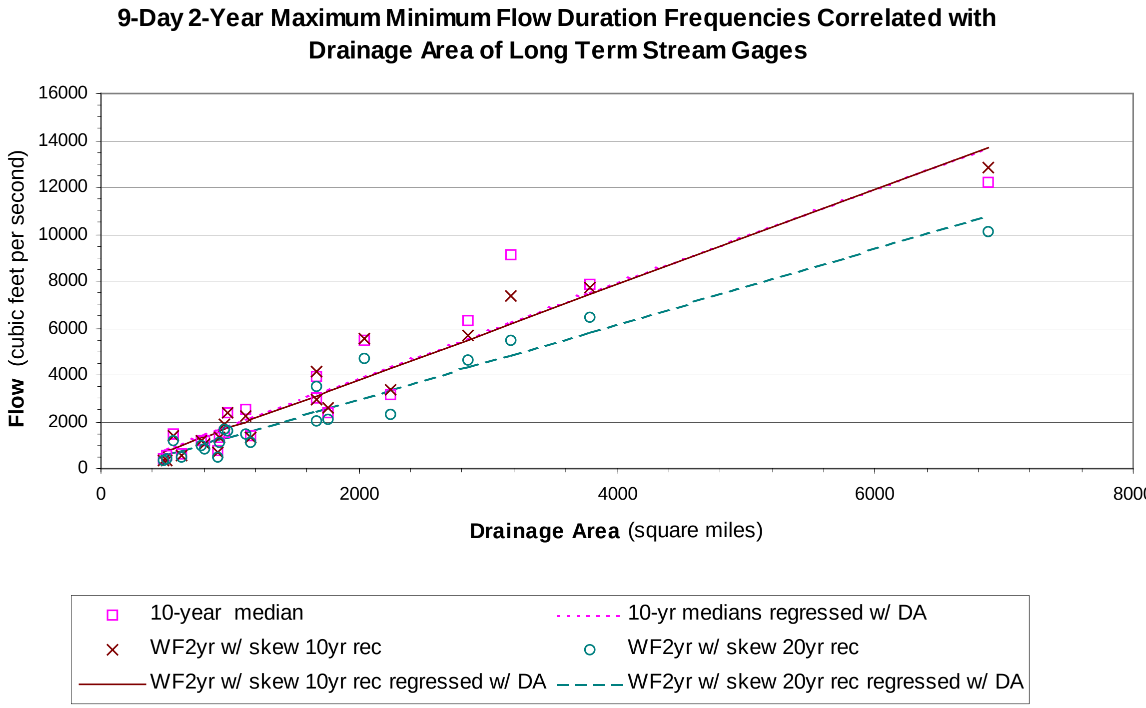

Figure 14. Graph of linear regressions of ${}_{9\ min}Q_{max\ 2}$ with drainage area.

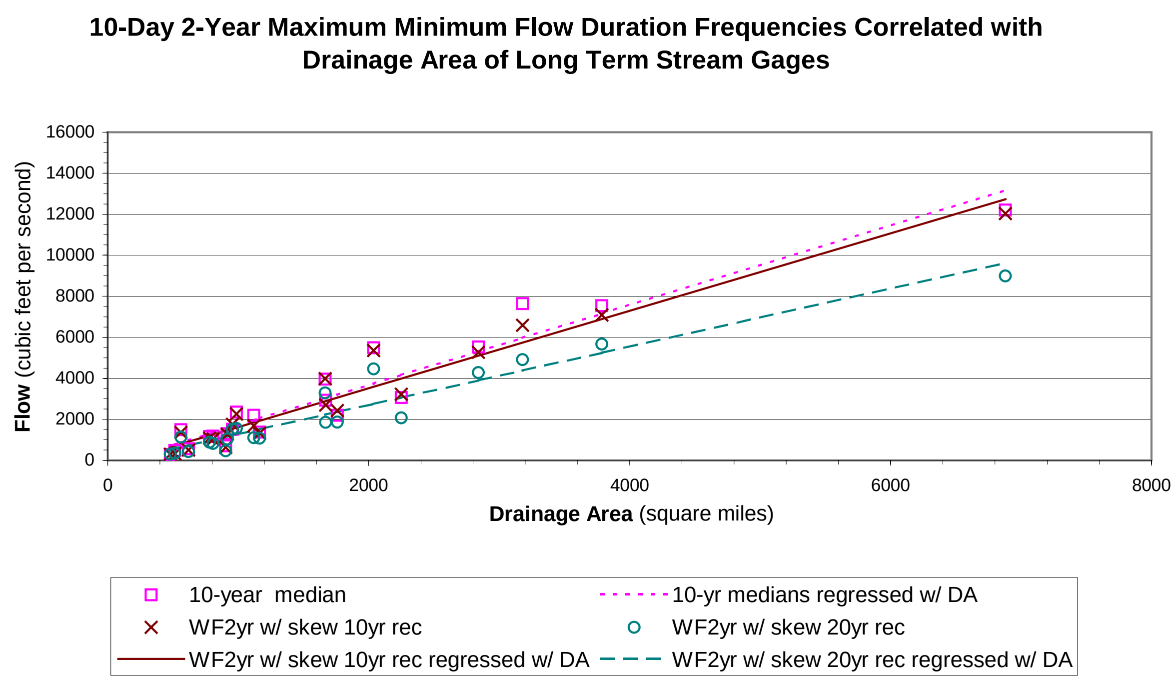

Figure 15. Graph of linear regressions of ${}_{10\ min}Q_{max\ 2}$ with drainage area.

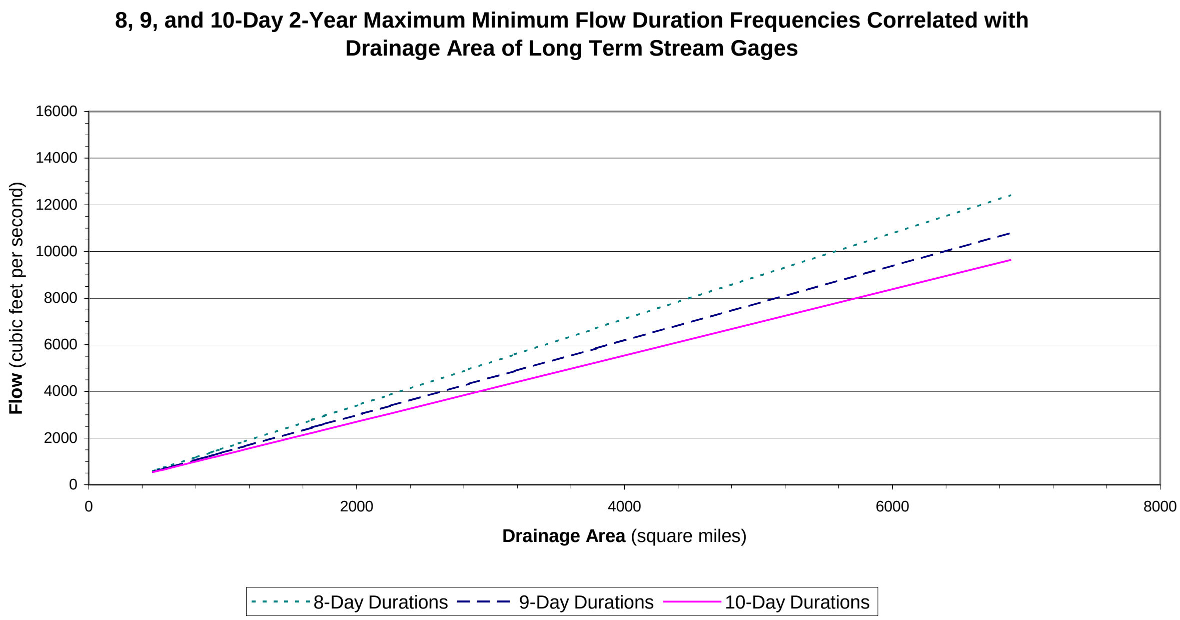

Figure 16. Graph of linear regression lines of $_{8,\ 9,\ \text{and}\ 10\ \text{min}}Q_{\text{max}\ 2}$ with drainage area.

Monthly precipitation and PDSI for the three monitoring sites

monthly precipitation totals are expresed in inches; PDSI = Palmer Drought Severity Index
Source: National Oceanic and Atmospheric Administration

Nevada Water Plant

	precipitation 1998	1998 % of mthly avg	Mo. Division 3 PDSI	precipitation 1999	1999 % of mthly avg	Mo. Division 3 PDSI	precipitation 2000	2000 % of mthly avg	Mo. Division 3 PDSI	long term Avg Pcp
January	2.06	123	1.36	2.31	138	3.54	0.73	44	-2.67	1.672
February	0.59	35	1.44	1.87	110	3.13	2.08	122	-2.28	1.704
March	5.33	174	2.46	3.05	99	2.65	4.86	158	-2.34	3.069
April	3.24	77	2.33	10.5	249	3.08	1.04	25	-2.99	4.225
May	2.28	46	0.99	7.97	160	3.12	3.71	74	-2.95	4.991
June	4.59	84	1.69	9.5	175	3.22	7.67	141	-2	5.437
July	6.72	186	2.92	0.64	18	-0.62	2.95	82	-1.48	3.606
August	2.59	68	2.41	4.38	115	-0.95	0.07	2	-1.89	3.815
September	9.14	206	2.97	3.37	76	-1.15	2	45	-2.17	4.44
October	9.38	261	3.87	0.68	19	-1.9	2.33	65	-2.28	3.595
November	2.91	105	3.6	1.74	63	-2.76	1.97	71	-2.4	2.781
December	1.57	80	3.19	4.07	207	-2.39	1.15	58	-2.77	1.97
Total	50.4	120		50.08	119		30.56	73		41.929
Min	0.59			0.64			0.07			
Max	9.38			10.5			7.67			

Steffenville

	precipitation 1998	1998 % of mthly avg	Mo. Division 2 PDSI	precipitation 1999	1999 % of mthly avg	Mo. Division 2 PDSI	precipitation 2000	2000 % of mthly avg	Mo. Division 2 PDSI	long term Avg Pcp
January	1.16	76	0.31	4.06	265	2.83	0.73	48	-3.47	1.534
February	2.87	204	1.05	0.83	59	2.91	2.18	155	-3.25	1.41
March	4.73	169	1.99	2.02	72	2.53	1.59	57	-3.32	2.791
April	4.38	125	2.15	6.23	178	2.68	1.5	43	-3.69	3.494
May	7.02	161	1.43	4.17	95	-0.28	2.59	59	0.18	4.369
June	7.59	179	2.49	3.44	81	-0.28	8.42	199	1.22	4.238
July	NA	NA	2.9	1.51	39	-0.76	2.29	59	1.35	3.873
August	0.72	19	2.19	2.2	59	-1.4	4.08	109	1.99	3.735
September	5.26	135	2.01	6.08	156	-1.69	3.15	81	1.63	3.909
October	7.53	245	2.45	0.7	23	-2.11	2.26	74	1.51	3.068
November	5.42	209	2.56	0.21	8	-3.19	3.01	116	1.45	2.588
December	2.89	163	2.19	3.05	172	-3.12	1.08	61	1.1	1.777
Total	49.57	135		34.5	94		32.88	90		36.633
Min	0.72			0.21			0.73			
Max	7.59			6.23			8.42			

KCI

	precipitation 1998	1998 % of mthly avg	Mo. Division 1 PDSI	precipitation 1999	1999 % of mthly avg	Mo. Division 1 PDSI	precipitation 2000	2000 % of mthly avg	Mo. Division 1 PDSI	long term Avg Pcp
January	0.97	83	1.58	2.3	198	4.3	0.46	40	-2.42	1.164
February	1.1	83	1.7	1.71	129	4.12	2.21	167	-2.16	1.323
March	3.44	136	2.77	1.49	59	3.58	2.93	116	-2.33	2.531
April	2.15	62	2.84	8.43	244	4.23	0.66	19	-2.9	3.453
May	1.75	32	1.47	5.62	103	4.15	4.55	84	-3.41	5.435
June	9.22	201	2.28	8.67	189	3.94	7.55	165	0.8	4.581
July	4.97	112	2.7	0.51	12	-0.45	6.02	136	1.07	4.429
August	3.61	101	2.37	1.56	43	-1.09	0.5	14	0.8	3.588
September	8.69	184	2.9	5.32	112	-0.73	3.13	66	0.54	4.73
October	8.15	242	3.97	0.67	20	-1.37	3.55	106	0.46	3.362
November	4.3	186	4.69	1.63	71	-2.04	2.59	112	0.41	2.308
December	1.19	74	4.33	2.18	135	-2.06	0.81	50	0.14	1.609
Total	49.54	129		40.09	104		34.96	91		38.493
Min	0.97			0.51			0.46			
Max	9.22			8.67			7.55			

Table 1. Monthly precipitation and PDSI for the three monitored sites.

Median, Duration and frequency of river discharge (Q) that assumes riparian wetland hydrology for the three gages.

	10 years of daily records; median of annual maximum minimums (cubic feet per second)	regression equa. applied	$({}_{ith\ min}Q_{max\ 2})$ 10 years of daily records; 2 year frequency of occurrence adjusted for station skew (cubic feet per second)	years 1990-1999 regression equa. applied	$({}_{ith\ min}Q_{max\ 2})$ 20 years of daily records; 2 year frequency of occurrence adjusted for station skew (cubic feet per second)	years 1980-1999 regression equa. applied	fld stage & Q (ft & cfs)	10-year median of annual maximum minimums stage (ft)	frequency of occurrence (k years) of $({}_{ith\ min}Q_{max\ kth})$ for bankfull discharge using data years '90-'99
Platte River at Sharps Station									
drainage area=2380 square miles									
9 day duration									
April 14 thru Oct. 18	4155	4636	4913	4559	4221	3594	26/10200	17	5
North Fork Salt River at Shelbina									
drainage area=481square miles									
10 day duration									
April 9 thru Oct. 23	330	710	309	643	299	540	12/3430	7	35
Little Osage River at Horton									
drainage area=540 square miles									
10 day duration									
April 6 thru Oct. 26	1385	825	1025	754	NA*	624	41/2431	37	5 (yrs 1991-2000)

* NA: the river gage on the Little Osage River at Horton had less than twenty years of daily records.

Table 2. Median, duration, frequency and flow for assumed wetland hydrology at the three monitored sites.

Correlation of river peak stages with wetland peak stages

For each monitoring site and their respective rivers, flood peak stage for the river and the wetland
were correlated for each flood event that inundated the wetland and occurred during the two year monitoring period

Platte River

Date	River peak stage	River peak elevation	Wetland peak stage	Wetland peak elevation	R — Correlation coefficient of river gage with wetland gage
4/19/1999	29.73	783.96	5.92	771.85	0.997828
4/30/1999	28.51	782.74	4.41	770.34	
6/28/1999	26.92	781.15	2.69	768.62	
6/26/2000	27.02	781.25	2.56	768.49	

North Fork Salt River

Date	River peak stage	River peak elevation	Wetland peak stage	Wetland peak elevation	R
1/22/1999	18.5	683.08	18.51	683.09	0.99915
4/23/1999	12.98	677.56	12.38	676.96	
4/28/1999	12.6	677.18	12.06	676.64	
5/7/1999	17.61	682.19	17.2	681.78	
5/17/1999	16.34	680.92	15.94	680.52	
6/26/2000	11.7	676.28	10.89	675.47	

Little Osage River

Date	River peak stage	River peak elevation	Wetland peak stage	Wetland peak elevation	R
4/17/1999	45.02	745.02	45.21	749.13	
4/29/1999	45.92	745.92	45.5	749.42	0.944659
5/4/1999	44.34	744.34	44.72	748.64	
6/29/1999	43.42	743.42	44.34	748.26	
6/28/2000	42.07	742.07	42.11	746.03	

Table 3. Correlation of river peak stages with wetland peak stages.

Duration and Frequency Regression Equations

	10-year medians regressed with DA		10-year record regressed with DA; WF adjusted for station skew		20-year record regressed with DA; WF adjusted for station skew	
8-Day 2-Year Duration and Frequency						
	correlation coeficient =	0.95	correlation coeficient =	0.97	correlation coeficient =	0.97
	line slope =	2.161037	line slope =	2.281365	line slope =	1.848296
	y intercept =	-109.094	y intercept =	-288.956	y intercept =	-299.807
	Q=DA(2.161)-109.094		Q=DA(2.281)-288.956		Q=DA(1.848)-299.807	
9-Day 2-Year Duration and Frequency						
	correlation coeficient =	0.95	correlation coeficient =	0.97	correlation coeficient =	0.97
	line slope =	2.018331	line slope =	2.031356	line slope =	1.59993
B 4	y intercept =	-167.135	y intercept =	-275.964	y intercept =	-213.528
	Q=DA(2.018)-167.135		Q=DA(2.031)-275.964		Q=DA(1.600)-213.528	
10-Day 2-Year Duration and Frequency						
	correlation coeficient =	0.96	correlation coeficient =	0.97	correlation coeficient =	0.96
	line slope =	1.947182	line slope =	1.887389	line slope =	1.421198
	y intercept =	-226.218	y intercept =	-264.85	y intercept =	-143.196
	Q=DA(1.947)-226.218		Q=DA(1.887)-264.850		Q=DA(1.421)-143.196	

WF=duration frequency calculated with the computer software, Duration Frequency for Windows, by Hydrosphere Inc.
Q=discharge in cubic feet per second
DA=drainage area in square miles

Table 4. Duration and frequency regression equations.

8-Day 2-Year Duration and Frequency analysis and ancillary data

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	S
05502500	SALT RIVER NEAR SHELBINA, MO.	481	553	7	453	454	930	1.00	808	589	12	6	6	5	8270
06819500	ONE HUNDRED AND TWO RIVER AT MARYVILLE M	515	564	5	493	483	1004	0.98	886	652	14	3	11	9	11400
07057500	NORTH FORK RIVER NEAR TECUMSEH, MO	561	1495	3	1434	1206	1103	0.84	991	737	20	2	18	17	15900
05500000	SOUTH FABIUS RIVER NEAR TAYLOR, MO	620	611	4	632	556	1231	0.88	1126	846	9.5	1	8.5	5.5	10100
07013000	MERAMEC RIVER NEAR STEELVILLE, MO	781	1335	4	1328	1044	1579	0.79	1493	1144	12	2	10	8	17700
07016500	BOURBEUSE RIVER AT UNION, MO	808	1190	4	1161	967	1637	0.83	1554	1194	15	1	14	11	17700
05514500	CUIVRE RIVER NEAR TROY, MO	903	787	6	821	625	1842	0.76	1771	1369	21	4	17	15	29100
07018500	BIG RIVER AT BYRNESVILLE	917	1385	7	1430	1214	1873	0.85	1803	1395	16	1	15	9	19900
07037500	ST. FRANCIS RIVER NEAR PATTERSON, MO	956	1700	8	2142	1867	1957	0.87	1892	1467	16	5	11	8	39100
07052500	JAMES RIVER AT GALENA, MO	987	2355	6	2506	1736	2024	0.69	1963	1524	15	2	13	9	23300
06908000	BLACKWATER RIVER AT BLUE LICK, MISSOURI	1120	3645	20	3022	2126	2311	0.70	2266	1770	24	6	18	4	13500
07186000	SPRING RIVER NEAR WACO, MO	1164	1575	4	1440	1222	2406	0.85	2367	1852	19	1	18	15	20600
07067000	CURRENT RIVER AT VAN BUREN, MO	1667	4130	5	4426	3719	3493	0.84	3514	2781	20	1	19	15	30300
06899500	THOMPSON RIVER AT TRENTON MO	1670	3330	6	3278	2251	3500	0.69	3521	2787	20	1	19	14	34800
06820500	PLATTE RIVER NEAR AGENCY, MO.	1760	2910	12	2843	2364	3694	0.83	3726	2953	20	5	15	8	21400
07068000	CURRENT RIVER AT DONIPHAN,MO.	2038	5560	4	5887	4915	4295	0.83	4361	3467	13	0	13	9	32700
06897500	GRAND RIVER NEAR GALLATIN MO	2250	3665	10	4133	2632	4753	0.64	4844	3859	26	4	22	16	32000
06933500	GASCONADE RIVER AT JEROME MO	2840	6850	6	6529	5255	6028	0.80	6190	4949	15	1	14	9	39700
06934000	GASCONADE RIVER NEAR RICH FOUNTAIN, MO.	3180	9810	8	8902	6446	6763	0.72	6966	5578	20	1	19	12	30500
07019000	MERAMEC RIVER NEAR EUREKA, MO	3788	8910	8	8684	7149	8077	0.82	8353	6702	18	1	17	10	42900
06902000	GRAND RIVER NEAR SUMNER MO	6880	12900	21	14257	11801	14759	0.83	15407	12416	26	7	19	5	67400

B 5

Data Descriptions

A, USGS river gage identification number
B, USGS station name
C, drainage area of stream flow gage in square miles
D, 10 year median of the annual maximum of the moving eight day minimum flow
E, river stage produced by the stream flow value, D
F, eight day minimum daily mean flow with a 50 % probability of being equaled or exceeded in a given year calculated with statistical skew for the most recent 10 years
G, eight day minimum daily mean flow with a 50 % probability of being equaled or exceeded in a given year calculated with statistical skew for the most recent 20 years
H, results of regression of D with C; regression equation is applied to drainage area of flow gage to estimate flow parameter
I, ratio of G divided by F
J, results of regression of column F with column C; regression equation is applied to drainage area of flow gage to estimate flow parameter
K, results of regression of column G with column C; regression equation is applied to drainage area of flow gage to estimate flow parameter
L, flood stage (in vertical feet) of the stream gage as designated by the National Weather Service
M, stage (in vertical feet) of the stream gage at zero flow
N, difference between flood stage and stage (in vertical feet) at zero flow
O, difference between flood stage and the stage of the ${}_{ith\ min}Q_{max\ kth}$ of the most recent 10 year record of daily stream flow
S, instantaneous peak flow with a 50 % probability of being equaled or exceeded in any given year.

Table 5. Results of 8-day two-year duration and frequency analysis.

Major and detailed land uses of drainage areas to the three monitoring sites.

Source: USGS Nationwide Landuse Classification

		Platte	River	basin.		
Major	Land	Use	Name	and	Code	Area
------------------------				(acres)		percent
Urban	or	Built-up	Land	19312		0.012393
Agricultura	Land			1496396		0.960256
Forest	Land			37660		0.024167
Water				1986		0.001274
WetLand				363		0.000233
Barren	Land			2543		0.001632
Unclassified				71		4.56E-05
========================						
Total				1558331		

		Little	Osage	River	Basin.	
Major	Land	Use	Name	and	Code	Area
------------------------				(acres)		percent
Urban	or	Built-up	Land	1766		0.005178
Agricultura	Land			297904		0.873414
Forest	Land			35243		0.103328
Range	Land			2744		0.008045
Water				307		0.0009
WetLand				60		0.000176
Barren	Land			3042		0.008919
Unclassified				14		4.1E-05
========================						
Total				341080		

	North	Fork	Salt	River	basin.	
Major	Land	Use	Name	and	Code	Area
------------------------				(acres)		percent
Urban	or	Built-up	Land	3494		0.012712
Agricultura	Land			241517		0.878691
Forest	Land			29414		0.107014
Water				416		0.001513
Barren	Land			19		6.91E-05
========================						
Total				274860		

		Platte	River	basin.		
========================						
Detailed	Land	Use	Name	and	Code	Area

Urban	or	Built-up	Land	(acres)		percent
RESIDENTIAL-11				8973		0.005758
COMMER	AND	SERVICES-12		2613		0.001677
INDUSTRIAL-13				578		0.000371
TRANS,	COMM,	UTIL-14		4925		0.00316
MXD	URBAN	OR	BUILT-UP-	1255		0.000805
OTHER	URBAN	OR	BUILT-UP-	968		0.000621
Subtotal				19312		0.012393
Agricultura	Land					
CROPLAN	AND	PASTURE-21		1495880		0.959924
CONFINEI	FEEDING	OPS-23		151		9.69E-05
OTHER	AGRICULT	LAND-24		365		0.000234
Subtotal				1496396		0.960256
Forest	Land					
DECIDUOI	FOREST	LAND-41		37660		0.024167
Subtotal				37660		0.024167
Water						
LAKES-52				364		0.000234
RESERVOIRS-53		(includes Smithvil Res		1622		0.001041
Subtotal				1986		0.001274
WetLand						
NONFORE	WETLAND-62			363		0.000233
Subtotal				363		0.000233
Barren	Land					
STRIP	MINES-75			1318		0.000846
TRANSITI(	AREAS-76			1225		0.000786
Subtotal				2543		0.001632
Unclassified						
				71		4.56E-05
Subtotal				71		4.56E-05
========================						
Total				1558331		

		Little	Osage	River	Basin.	
========================						
Detailed	Land	Use	Name	and	Code	Area

Urban	or	Built-up	Land	(acres)		percent
RESIDENTIAL-11				405		0.001187
COMMER	AND	SERVICES-12		72		0.000211
INDUSTRIAL-13				19		5.57E-05
TRANS,	COMM,	UTIL-14		625		0.001832
MXD	URBAN	OR	BUILT-UP-	605		0.001774
OTHER	URBAN	OR	BUILT-UP-	40		0.000117
Subtotal				1766		0.005178
Agricultura	Land					
CROPLAN	AND	PASTURE-21		297893		0.873382
OTHER	AGRICULT	LAND-24		11		3.23E-05
Subtotal				297904		0.873414
Forest	Land					
DECIDUOI	FOREST	LAND-41		31540		0.092471
MIXED	FOREST	LAND-43		3703		0.010857
Subtotal				35243		0.103328
Range	Land					
HERBACE	RANGELAND-31			2371		0.006951
SHRUB	&	BRUSH	RANGELA	373		0.001094
Subtotal				2744		0.008045
Water						
RESERVOIRS-53				307		0.0009
Subtotal				307		0.0009
WetLand						
FORESTE	WETLAND-61			60		0.000176
Subtotal				60		0.000176
Barren	Land					
STRIP	MINES-75			3042		0.008919
Subtotal				3042		0.008919
Unclassified						
				14		4.1E-05
Subtotal				14		4.1E-05
========================						
Total				341080		

		NF	Salt	River	basin.	
========================						
Detailed	Land	Use	Name	and	Code	Area

Urban	or	Built-up	Land	(acres)		percent
RESIDENTIAL-11				1992		0.007247
COMMER	AND	SERVICES-12		1124		0.004089
INDUSTRIAL-13				98		0.000357
TRANS,	COMM,	UTIL-14		18		6.55E-05
MXD	URBAN	OR	BUILT-UP-	137		0.000498
OTHER	URBAN	OR	BUILT-UP-	125		0.000455
Subtotal				3494		0.012712
Agricultura	Land					
CROPLAN	AND	PASTURE-21		241410		0.878302
CONFINEI	FEEDING	OPS-23		14		5.09E-05
OTHER	AGRICULT	LAND-24		93		0.000338
Subtotal				241517		0.878691
Forest	Land					
DECIDUOI	FOREST	LAND-41		29414		0.107014
Subtotal				29414		0.107014
Water						
RESERVOIRS-53				416		0.001513
Subtotal				416		0.001513
Barren	Land					
TRANSITI(	AREAS-76					
Subtotal	19			19		6.91E-05
========================						
Total				274860		

Table 6. Landuse in drainage basins of the three monitored sites.

B 6

Above: Monitored site in Platte Falls CA looking away from Platte River, October 1998.

Below: Monitored site in Platte Falls CA looking away from Platte River, November 1999.


Above: Arrow-Wood CA monitored riparian wetland, October 1998.

Below: Arrow-Wood CA monitored riparian wetland, February 2000.



Above: Little Osage River oxbow, October 1998.

Below: Little Osage River oxbow, November 1999.